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16. ABSTRACT

All of the Great Lakes are changing; however, the lower lakes, because of their increased productivity, are changing at a much faster rate. This condition is reflected in the overall nutrient and biomass content of the individual lakes. The nutrient concentrations of the lower lakes are 4-8 times higher than those in the upper lakes. The increase in phosphorus in the lower lakes has resulted in dramatic increases in phytoplankton biomass, as well as in shifts in the biomass to a greater percentage of bluegreen algae.

Changes have occurred in the zooplankton communities. Here, again, the biomass increases to match the increase in phytoplankton; however, there is also an increase in the more eutrophic taxa. The relative change in the percent calanoid zooplankton population in the lower lakes indicates the severity of the productivity problem in Lakes Erie and Ontario.

Changes in the biota of a lake can result from three major types of influences. The first is change in the physical environment. The second type of change is associated with direct toxicity. There is very little evidence to suggest that this has occurred in Lakes Erie and Ontario. The third type of influence, and, probably, the most prevalent today, are changes resulting from altered food supplies.

The large phytoplankton blooms that were associated with the degradation of Lake Erie were often noted in the late 1960's. These populations have been recorded on a decreasing frequency in the last five years. Some positive changes have occurred since 1972; a decrease has occurred in phosphorus concentrations in Lake Ontario. In the nearshore area adjacent to Toronto, Canada, the decrease has been most dramatic.

During the period since the last conference at Buffalo, the primary concern has shifted from eutrophication and changing fish stocks to contamination of fish and birds with heavy metals and toxic organic substances, as well as a concern for public health. Even though the Lake Ontario ecosystem can support a limited fish population, contamination of the fish with mirex has greatly impaired the use of the fishery.

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ECOSYSTEM CHANGES IN LAKES ERIE AND ONTARIO

NELSON A. THOMAS

Since the last conference on The Changes in the Biota of Lakes Erie and Ontario, held in April of 1968, a great deal of water has flowed through these Lakes. Specifically, the water has changed almost five times in Lake Erie, and 1¼ times in Lake Ontario. Sufficient time has passed so that we are able to reflect on changes that have occurred both within the lakes and their basins that affect the flora and fauna. As a result of much of the publicity during the late 1950's and early 1960's concerning the degraded quality of Lakes Erie and Ontario, Water Quality Agreements were signed in 1972 and 1978 between Canada and the United States. One of the main provisions was to limit the phosphorus in sewage treatment plant effluents. Many states and the Canadian provinces have passed legislation which also enhanced the water quality of these lakes. These include detergent bans in New York and Michigan and reduction in phosphate detergents in the Province of Ontario. In addition to the legislative changes that have occurred regarding the lakes, there have been periodic changes in climatic conditions which also greatly affect water quality. As the rainfall decreases, the diffuse source pollutant load drastically decreases, affecting plankton growth through increased clarity.

During the period between 1968 and 1980, there have been several large-scale studies on Lakes Ontario and Erie. I will review some of the major observations that reflect changing conditions which, in turn, may affect the flora and fauna. These studies not only provide another point in time to examine the quality of the lakes, but they also provide greater insight into the processes that are going on within the lakes that affect the biota.

The way in which we examine the Great Lakes now is greatly different from the way it was viewed at the time of the past conferences. Recently, there has been a great deal of emphasis on taking a systems approach to examining the Great Lakes ecosystem. Dr. Jack Vallentyne has put together a review (I.J.C. 1978) of this approach for the International Joint Commission. This approach has been endorsed by almost every organization and government body present in the Great Lakes basin. Basically, he suggests that when we look at ecological changes that may be occurring, we should examine all the actions that may have caused the changes and critically note the consequences of these changes. This would mean that we do not look at individual aspects of the Great Lakes ecosystem without considering the relationship of these individual elements within the system (including social and economic aspects). This is a very difficult concept to implement, since it requires a substantially different type of thinking and philosophical understanding. The difficulty arises because that mode of thought was not considered during the era in which most of the present day scientists received their education. As students of today are exposed to this holistic approach, their thinking will carry on into future studies and management decisions.

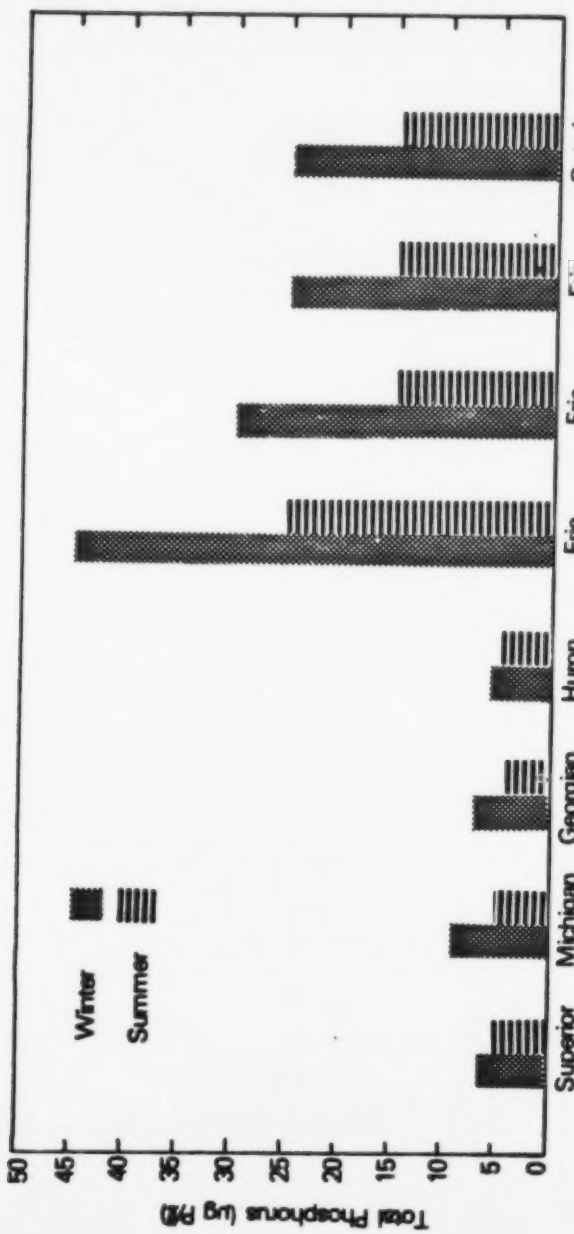

Fig. 1. Total phosphorus concentrations in the open waters of the Great Lakes from IJC 1976.

I would like to adopt Dr. Vallentyne's ecosystem approach and set a slightly different tone for the discussion of the broad changes that have occurred in the biota of Lakes Erie and Ontario. In our discussions concerning the changes in the biota, it would be beneficial if we could relate some of these changes to their causes as well as the consequences. I notice that the formats for the previous conferences were designed to consider the biota, and then, approximately two years later, to review chemical changes, and ultimately two or three years later, to examine the physical aspects of the lakes. I believe if we could try to relate some of the chemical and physical changes to the bioperturbations that we are now seeing, it will help us to grasp an understanding of how man has impacted the Great Lakes. An examination of the flora and fauna yields a broad perspective and understanding of the stresses that have been placed on the lakes and provides qualitative indications of the quality of the system. Usually, such observations cannot explain why these changes have taken place, nor how they could be rectified. To document changes through time, systematic surveys at an extraordinarily detailed level are required to separate true changes from random or cyclical biological variations. We have had glimpses of the composition of the flora and fauna since the late 1600's. The number of in-depth studies which provide a basis for the detailed definition of many of the populations in the lakes are extremely limited. I think we all recognize the problems of attempting to mount in-depth surveys of individual segments of the biota, and, at the same time, attempt to integrate them into a more comprehensive study which involves other disciplines. If, however, we are to understand the causes of some of the changes in the biota that we know have taken place, and will continue to take place in the future, we must strive to bring together interdisciplinary studies.

In reviewing the changes that have occurred in the lower lakes, it is important to look at the potential for change. As ecosystems become stressed, the potential for species shifts increases. Changes in the biota and chemistry of the lower lakes have been noted over the last twenty years as indicated by the previous conferences of this group and by the International Joint Commission's reports on the lower lakes (ILEWPB 1969).

A comparison of the lower lakes (Erie and Ontario) to the three upper lakes (Michigan, Superior and Huron) provides insight into the relative changes that have occurred to date. In examining the nutrient enrichment and resulting productivity, the effect of human population growth is very evident on the lower lakes. All of the Great Lakes are changing; however, the lower lakes, because of their increased productivity, are changing at a much faster rate. This condition is reflected in the overall nutrient and biomass content of the individual lakes. The nutrient concentrations of the lower lakes are 4-8 times higher than those in the upper lakes (Figure 1). The increase in phosphorus in the lower lakes has resulted in dramatic increases in phytoplankton biomass, as well as in shifts in the biomass to a greater percentage of bluegreen algae (Figure 2). Changes in the phytoplankton have caused many nuisance problems, the most severe being associated with water supplies. The time between filter back washes at the water filtration plants has been greatly reduced, and taste and odor problems often have developed which require the use of additional chlorine or activated carbon. Other biotic changes occur further up the trophic structure as a result of phytoplankton changes. These changes are reflected in the zooplankton communities (Figure 3). Here, again, the biomass

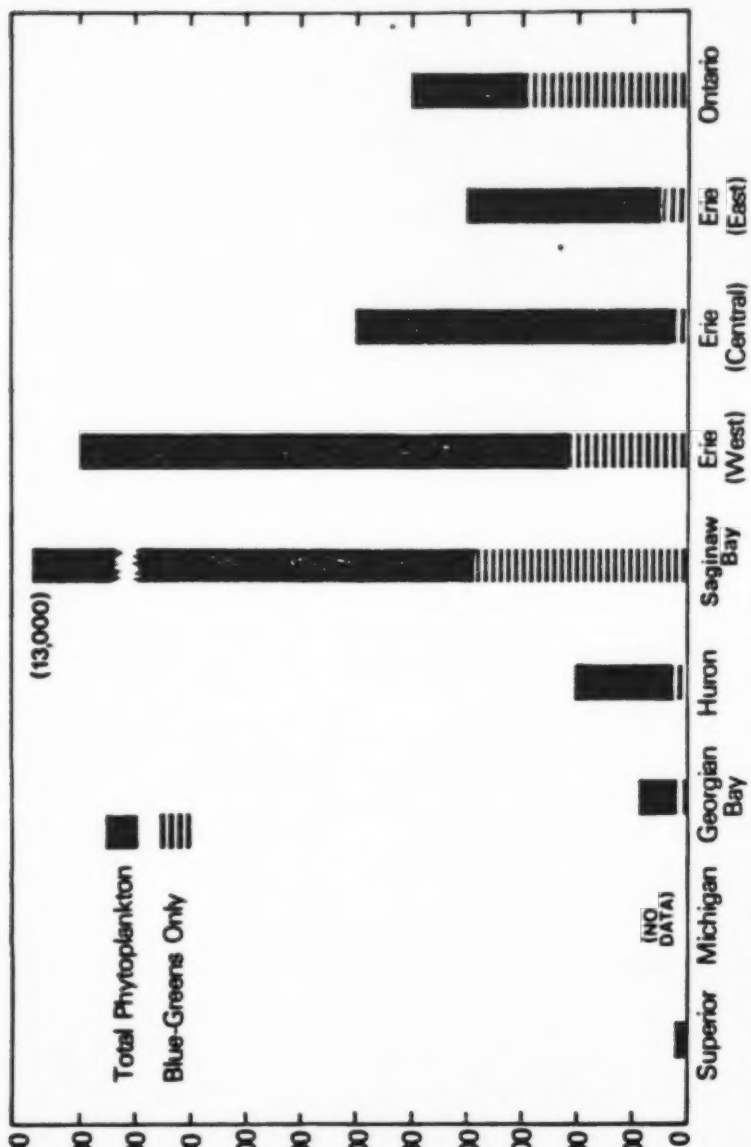

Fig. 2. Phytoplankton biomass concentrations in the open waters of the Great Lakes from IJC 1976.

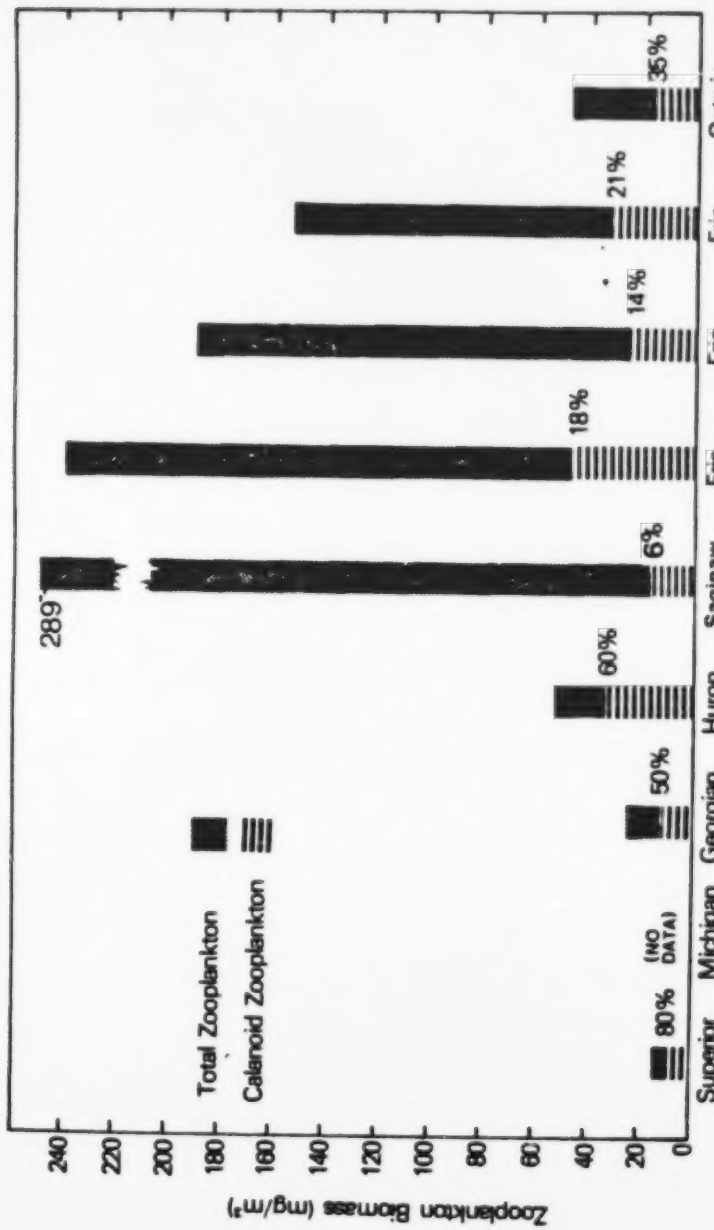

Fig. 3. Zooplankton biomass concentrations in the open waters of the Great Lakes from IJC 1976.

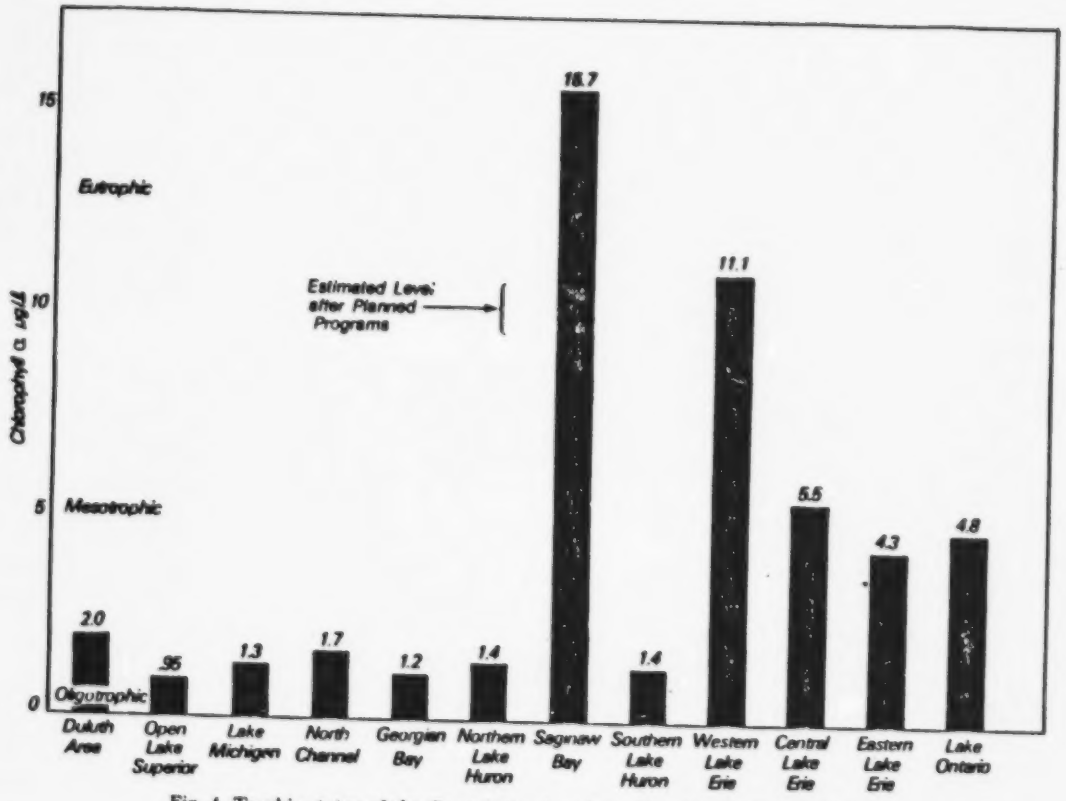

Fig. 4. Trophic status of the Great Lakes based on chlorophyll *a* from IJC 1976.

increases to match the increase in phytoplankton; however, there is also an increase in the more eutrophic taxa. The relative change in the percent calanoid zooplankton population in the lower lakes indicates the severity of the productivity problem in Lakes Erie and Ontario. The overall productivity of Lakes Erie and Ontario are also reflected in the chlorophyll measurements (Figure 4). These lakes contain at least three times the concentration of chlorophyll as compared to the upper lakes.

The comparison of the lower lakes to the upper lakes indicates the influence of man on the watershed and his discharge of phosphorus into the lakes. Historically, Lake Erie has been noted for its large production of fish; therefore, because of the nature of the drainage areas surrounding the Western Basin, it is logical to assume that the lake was always more productive than the upper lakes. However, the changes that have occurred in Lake Erie over the last century are even more dramatic. Often, we do not recognize that a species has been lost until it has completely vanished from a particular ecosystem, thereby making it almost impossible to determine the cause for the demise of that individual species.

Changes in the biota of a lake can result from three major types of influences. The first is change in the physical environment. In the lower lakes, this occurred at the turn of the last century with the draining of the large marshes, and the timber harvesting in the forests surrounding the lakes. These changes resulted in large increases in sediments entering the lakes, thereby reducing the photic zone, and limiting the growth of aquatic plants. The second type of change is associated with direct toxicity. There is very little evidence to suggest that this has occurred in Lakes Erie and Ontario. The only indication may be with the burrowing mayfly, *Hexagenia*, and the accumulation of toxics in fish resulting in bans. The third type of influence, and, probably, the most prevalent today, are changes resulting from altered food supplies. As phosphorus increases and enhances the growth of a particular type of alga, zooplankton respond to this increase, thereby increasing the competition for the remaining, and often more sensitive forms. Species shifts are frequently our best clue to the stresses now being placed on the Great Lakes Ecosystem.

To further provide discussion and interest in attempting to define some of the causes and consequences of the changes in the biota of the Great Lakes, I have listed (Table I), and plotted (Figures 5-8), many of the more significant biological and chemical changes in Lake Erie. The problem with attempting to document causation is that the changes occur over long periods of time, and studies are very intermittently dispersed. Some of the possible causes might even be called "folklore." If we do not attempt to define the causes of past changes, it is possible that environmental alterations that continue to take place will go unnoticed until it is too late.

The influence of man can be seen as early as 1900 with the slow increases of chloride (Figure 5) and the decrease in macrophytes (Figure 6). The decrease in macrophytes was most likely caused by the increase in suspended sediments. The changes that have taken place in Lake Erie can most closely be associated with the increase in various pollutant loadings to the lake. If one relates the various changes in the phytoplankton, bottom organisms and fish to the increase in urban and industrial pollutants, then the effect man had on

TABLE I
Recent changes and probable causes in Lake Erie 1900-1960

	Direction	Time	Cause
Rooted Aquatic Vegetation	Decrease	1900	Suspended Solids Increase
Phytoplankton	Increase	1935-1960	Phosphorus
Cladophora	Increase	1940-1950	Phosphorus
Mayfly (Hexagenia)	Increase Decrease	1940-1952 1953-1965	Phytoplankton Growth D.O. Depletion, DDT
Sludgeworms (Oligochaetes)	Increase	1950-1970	Organics from Waste Treatment Plants and Dead Plankton
Zooplankton	Increase	1945-1965	Increase in Phytoplankton
Whitefish	Decrease	1955	Overfishing, Suspended Solids Covering Spawning Beds, D.O. Loss from Hypolimnion of Central Basin
Lake Herring	Decrease	1930	Overfishing, Increase Suspended Solids
Perch	Increase	1955-1970	Increase in Zooplankton, Loss of Other Fish Species
Phosphorus	Increase	1945-1970	Detergents, Increase in Population
Chloride	Increase	1910-1960	Increase of Activity in Basin, Road Salt, Industry
D.O. Depletion Central Basin	Increase	1930-1970	Increase in Phytoplankton

stressing the system becomes quite clear. What is difficult to assess is the direct cause of some of these changes. The change in the oxygen depletion in the central basin is a complex issue and appears to have increased in severity from 1930 to 1970 (Figure 5). The changes that could be associated with oxygen depletion in the central basin hypolimnion are many. Among these changes are: (1) the shift of oligotrophic benthic organisms with their requirement for large amounts of dissolved oxygen to chironomidae larvae and oligochaeta worms that require little or no dissolved oxygen for extended periods (2) fish such as whitefish and lake trout cannot survive without a habitat of cold water containing oxygen during all months of the year (3) the recycle of nutrients and metals becomes quite different when the bottom sediments become anoxic (4) large amounts of phosphorus are released when the sediments are in reduced state.

Trends in the changes that might have occurred in the oxygen depletion rate in the Central Basin are undetectable over the ten year time span they have been measured. The changes that occur in the depletion rate appear to be related to the climatic conditions. Because the oxygen levels in Lake Erie are stable, it is an encouraging sign that we may be at a point where, with reduced productivity resulting from phosphorus control, the dissolved oxygen regimes would improve.

The large phytoplankton blooms that were associated with the degradation of Lake Erie were often noted in the late 1960's. These populations have been recorded on a decreasing frequency in the last five years. However, on occasion, they still occur. Reduction in the amounts of *Cladophora* have been

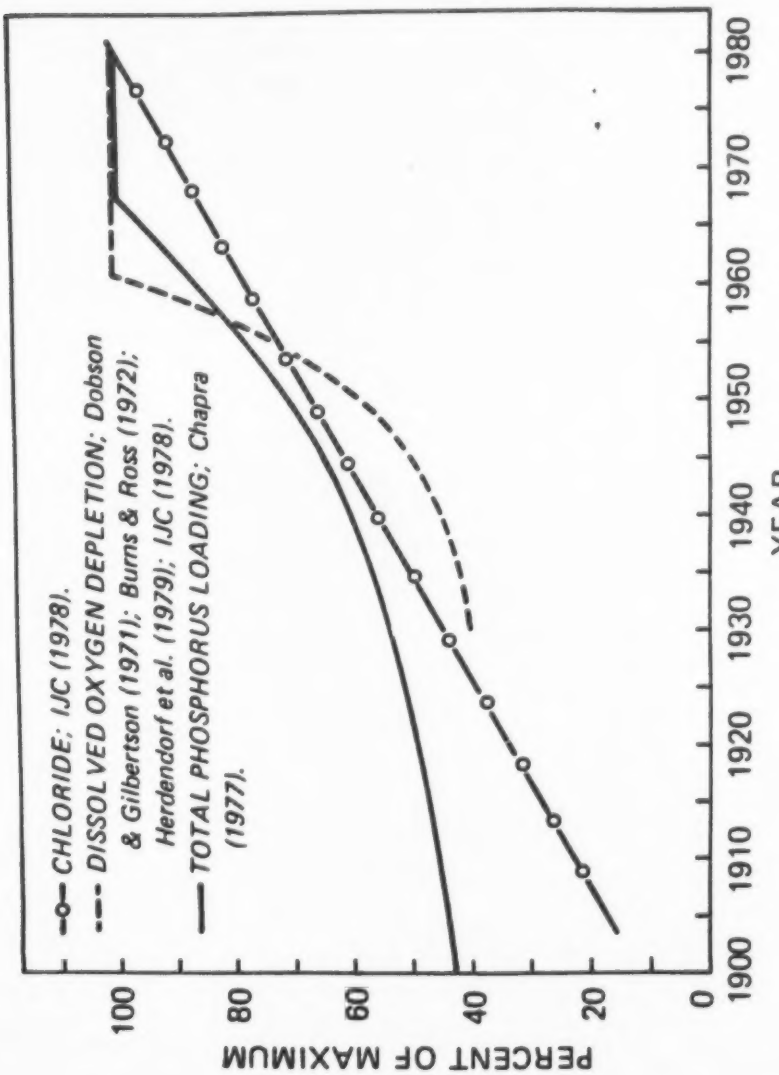

Fig. 5. Chemical changes in Lake Erie 1900-1980.

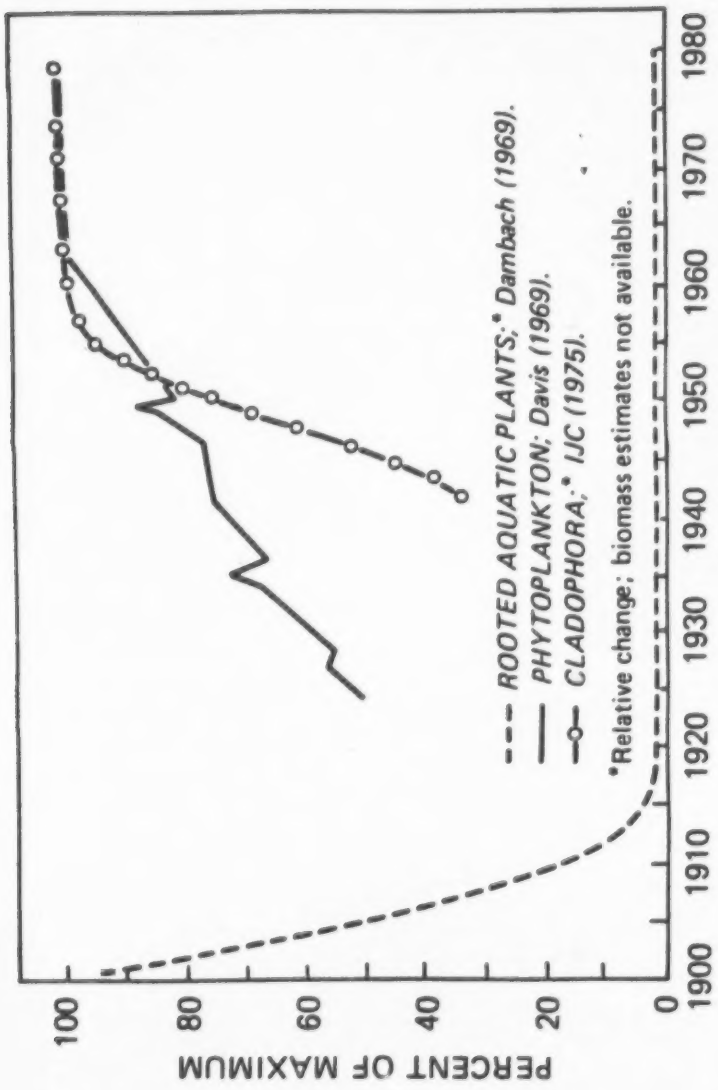

Fig. 6. Vegetation changes in Lake Erie 1900-1980.

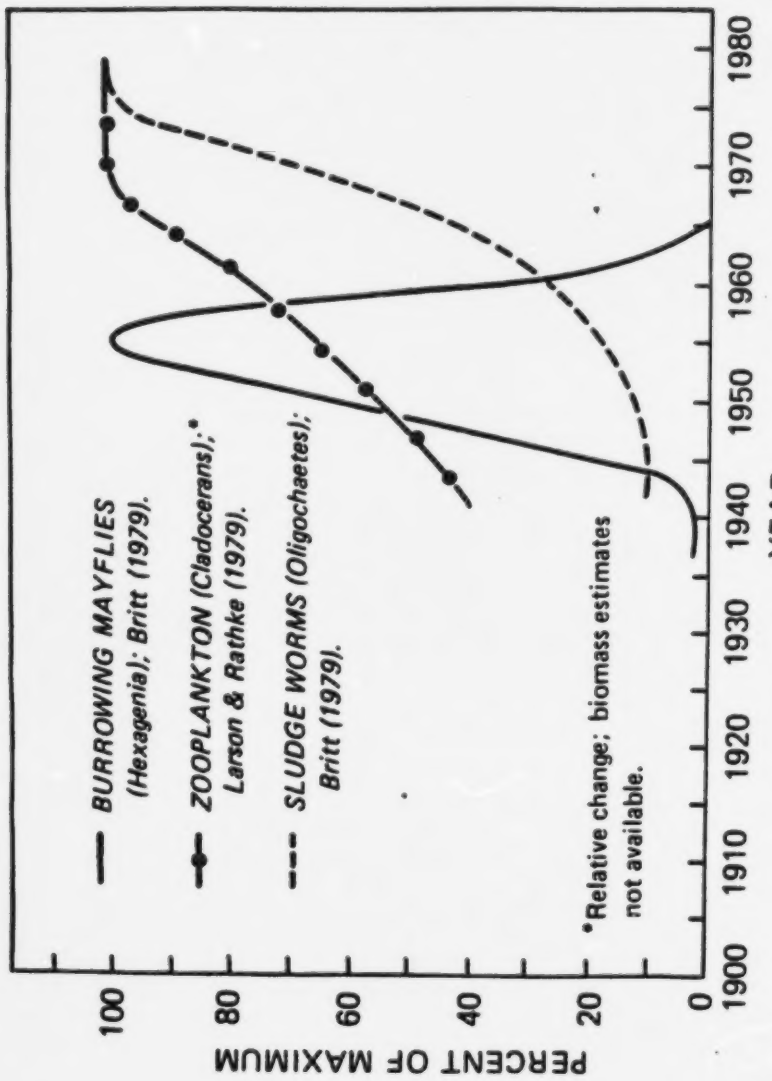

Fig. 7. Biological changes in Lake Erie 1900-1980.

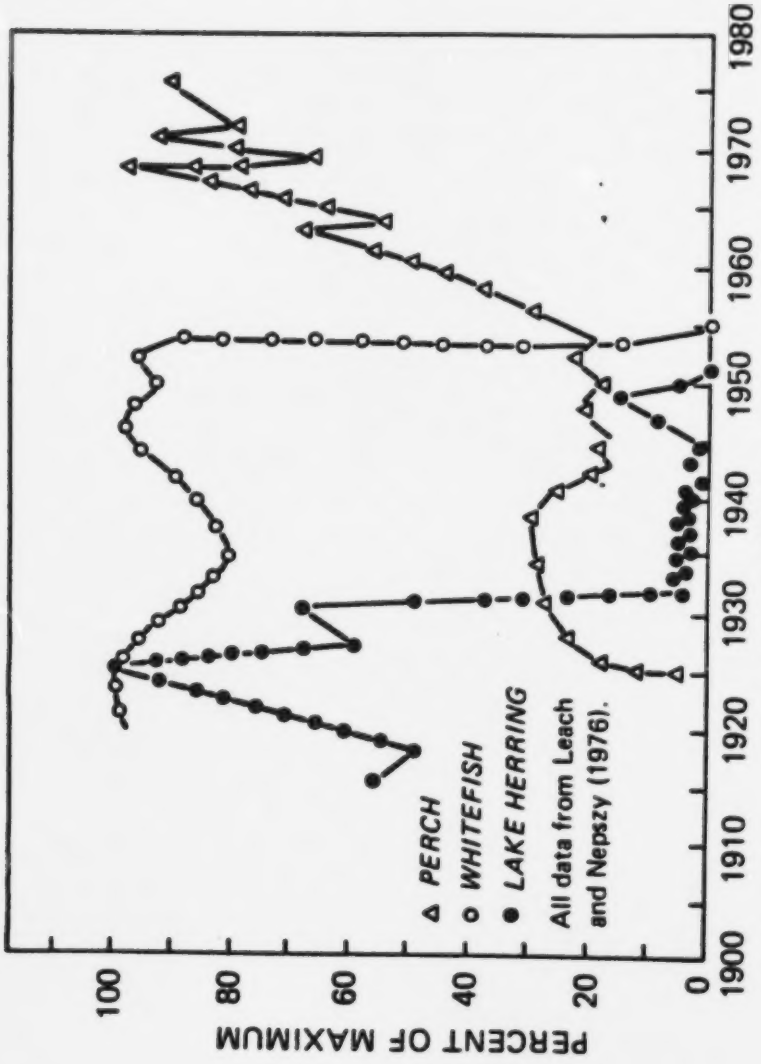

Fig. 8. Fisheries changes in Lake Erie 1900-1980.

noted by Dr. John Neil in the survey (I.J.C. 1975) conducted for the International Joint Commission. In conversations with representatives of the Province of Ontario, they have noted decreases since 1970 of *Cladophora* on the swim beaches in the Eastern Basin of Lake Erie.

Studies on the lakes from the early 1950's through 1968 (Britt 1979) indicate the demise of the burrowing mayfly *(Hexagenia)* population (Figure 7). This population was thought to have been completely eliminated as a result of dissolved oxygen reductions within the Western Basin and the replacement of the benthic fauna with midges. In reviewing DDT production figures, and DDT in fish and lake sediments, it appears that the highest plateau concentrations of DDT would also have been achieved in the early to mid-1950's. Mayfly populations dramatically decreased in many basins of the Great Lakes during the early 1950's. This phenomenon included Hamilton Harbor in Lake Ontario, Saginaw Bay in Lake Huron, and Green Bay in Lake Michigan. It would appear to be a more logical answer that exceeding a DDT threshold at this time caused the decrease in the mayfly populations, rather than to suggest that simultaneous oxygen depletions occurred in all of these basins.

Large changes have occurred in the fish stocks of Lake Erie (Figure 3). These changes resulted from overfishing, increased solids covering spawning areas, eutrophication through changing food supplies, and decreased water quality. Lake herring had its demise during the 1930's probably resulting from overfishing and increased competition. The whitefish population decreased rapidly in the period from 1950 to 1955. This fishery was depressed from both the loss of dissolved oxygen in the bottom waters of the Central basin and overfishing. The increase in perch and walleye populations resulted from decreased competition and changes in the food supplies. Some of the changes resulted from species such as smelt and alewife coming in from the ocean.

We are quite fortunate that Dr. Noel Burns took the initiative in bringing together many different studies on Lake Erie. In the special issue (Burns 1976) of the *Journal of the Fisheries Research Board of Canada*, "Lake Erie in the Early Seventies," there has been an attempt to discuss transport within the lake, lake sediments, sediment contaminants, sediment nutrients, cultural impact, various metal forms in the waters, activities in the watershed, physical processes within the lakes, nutrient budgets, bacterial distributions, phytoplankton, zooplankton, fisheries, and, finally, consideration of some of the processes that go on within the lake. In the final analysis, Dr. Burns attempted to connect schematically many of the important linkages for a whole lake system. This took the shape of an ecological model. While predictive capability awaits further development, Dr. Burns has described many of the important ecosystem linkages. This will be extremely useful in explaining some of the changes that have taken place. Likewise, on Lake Ontario we have been fortunate to have the IFYGL Project, which provided a format for merging many types of studies.

There have been hundreds of publications on the individual aspects of the IFYGL projects; however, only a few attempts to integrate the biological, chemical and physical components of Lake Ontario have been made. These attempts were mainly a result of numerical analyses which were designed to describe the inter-dependency of the many facets of a lake system. To date,

there have been very few examinations of the causes of the species change, or alteration in the size of the individual populations.

Phytoplankton studies indicate the degree to which man has placed stress upon that population. Many of the oligotrophic species like *Cyclotella* are no longer present (Stoermer 1980). The only species common to Lake Ontario and the Upper Lakes are eutrophic species. Diatoms, particularly *Stephanodiscus binderanus*, make up an important part of the flora during the summer and fall periods. This alga has been associated with cultural enrichment. As the dominant form along the nearshore, it suggests the influence of man on the phytoplankton of the Lake.

The zooplankton population has also been altered during the past 25 years. The major zooplankton population has shifted from *Diaptomus* sp. to *Bosmina longirostris* indicating a general degradation in water quality (McNaught 1980). The most abundant zooplankton are the cyclopoid copepods and cladocerans. Another indication of man's influence was in the fewer number of species of zooplankton found in the inshore areas adjacent to the major urban centers.

Cladophora was studied with regard to its relative coverage of the shoreline. This alga was found to cover 60% of the lake bottom from the Niagara River to Rochester, New York, and, almost 80% of the shoreline east of Rochester, thus indicating the response of this alga to the high phosphorus levels in the nearshore regions (Wezernak, *et al.* 1980). The benthos (Nalepa and Thomas 1976) were studied to examine the overall quality of the lake benthic flora. Pollution-tolerant oligochaetes were found to be most prevalent in the nearshore areas, especially off the cities of Rochester and Oswego. Another group, the Chironomidae, indicating degraded conditions, were most prevalent in the nearshore areas. In the deeper waters which contained many of the more sensitive organisms, *Pontoporeia affinis* populations indicate that the open lake had not been severely degraded. Based on the low abundance of the oligotrophic species and the high abundance of eutrophic species, it was concluded the most eutrophic areas were located off the Niagara River and Toronto. In the far eastern regions of Lake Ontario, the Bay of Quinte provided a study of a unique nature, since all levels of the biota could be studied in relation to severe nutrient loading. Many of the classical symptoms of advanced eutrophication were present. These symptoms included changes in the phytoplankton and the dominance of cladocerans in the zooplankton community. Dense algal growths and high turbidity have reduced the growth of macrophytes. The declining abundance of *Pontoporeia affinus*, especially in the areas known to have late summer oxygen depletion, further indicates the problems associated with enrichment. The fishery of Lake Ontario has been depressed for many years. This decline could possibly be related to a number of factors, including eutrophication, loss of spawning and nursery areas, and overfishing.

Some positive changes have occurred since 1972; a decrease has occurred in phosphorus concentrations in Lake Ontario. In the nearshore area adjacent to Toronto, Canada, the decrease has been most dramatic (I.J.C. 1978). Since 1972, when the detergent phosphorus content was lowered, and a more efficient removal procedure was initiated at the Toronto treatment plants, the nearshore reduction has been from 29 to 19 parts per billion. Decreases have

been also noted along other nearshore areas such as off Rochester, New York, and other urban United States areas. The phosphorus decrease in the open lake has been approximately 10%, a two parts per billion change. Most significant is the change in the total dissolved portion of the phosphorus load, indicating that the reductions may be more significant than had been first thought. These reductions are in the right direction and will have to be monitored with great intensity in the next few years to determine the resulting change in the biota of the lake. The target load of 7,000 metric tons per year of phosphorus adopted by the International Joint Commission is based on achieving a concentration of 10 parts per billion of total phosphorus in the open lake. It was believed that the 10 parts per billion phosphorus concentration would restore many of the species that have been replaced by the more eutrophic species. It has been generally concluded that the fish stocks will not be rehabilitated fully until the littoral zone has been reclaimed through pollution abatement. Many of the nursery sites and forms of larval food have been drastically altered over the last 25 years. Thus, the restoration of trophic linkages is vital to the rehabilitation of many of the fish species.

Many other changes have also taken place around Lakes Erie and Ontario, including the groups of investigators that are presently working on the lakes. The presence of various investigating teams is almost totally contingent upon various interests related to the regulatory agencies surrounding the lakes. The Canadian effort was most noticeable from 1968 to the present. There has been some indication that the level of commitment by the Canadian Federal Government has decreased, while the effort by the Ontario Ministry of the Environment has increased. The Canadian Federal Government has had many annual programs that have provided the long-term chemical data bases from which trend projections could be made in Lakes Erie and Ontario. This could result in a decrease in the amount of data available for open lake long-term analysis. The Ministry of the Environment has had an active program looking at several hundreds of stations in the nearshore areas of lakes. Their sampling will provide for long-term trend detection in the highly variable nearshore area. On the United States' side, many of the main lake studies have been carried on by the Ohio State University, which has been active in lake studies since the late 1800's. Their role has been to assess the water quality changes taking place in both the nearshore area and central basin of Lake Erie. The State University of New York, College at Buffalo, has also had a long history of research and monitoring, especially in the Eastern Basin of the lake, as well as the nearshore areas adjacent to the United States' side of Lakes Erie and Ontario. There also has been a shift from more research-oriented studies to monitoring studies in the last two or three years. This has resulted from the increased funds that are now available for monitoring activities, where, as in previous years, resources for these activities had not been readily available. The competition for research funds that are available is as keen, if not more so, as it has been in the past. This results from fluctuating budgets and inflation reducing the amount of work that can be done within a given budget. Changing agency emphasis also plays a vital role in determining the types of resources that will be available for conducting research on the Great Lakes.

During the period since the last conference at Buffalo, the primary concern has shifted from eutrophication and changing fish stocks to contamination of fish and birds with heavy metals and toxic organic substances, as well

as a concern for public health. Even though the Lake Ontario ecosystem can support a limited fish population, contamination of the fish with mirex has greatly impaired the use of the fishery. You are all very familiar with the problems related to the discharge of organic contaminants to the Great Lakes. It appears that we are quite fortunate in Lake Erie to have sufficient volume of suspended solids for the adsorption of organic contaminants and their ultimate disposition in the sediments. The high concentration of suspended solids lessens the dissolved fraction, thereby reducing the amounts of toxic organic substances which can be concentrated in the fish. However, the increased productivity and solids resulting from man's influence that may benefit the contaminant issue is the same problem that we are trying to eliminate because of eutrophication and fisheries problems.

The long-term prospect for the Great Lakes is most encouraging in that advanced waste treatment is proceeding in a very rapid rate. Most of the sewage treatment plants will be operational within the next five years. Response time for both Lakes Erie and Ontario to these abatement programs is fairly quick; therefore, results will, hopefully, be noticeable before the next conference.

The programs to contain organic contaminants are proceeding at a very rapid rate. Logically, then, the reductions in organic substances should proceed with the reductions in productivity, thereby lessening the chances for problems of bioaccumulation in the fish. The future restoration of the biota of the lower lakes is tied to the reduction in phosphorus inputs. Such phosphorus reductions would lead to lower productivity in the lakes. The diffuse source input of phosphorus is a large portion of the total input, and it appears that diffuse source control may be economically feasible in many of the sub-basins of Lake Erie. The combination of diffuse and point source controls may reduce phosphorus levels to the target loads (U.S. Army Corps of Engineers 1979). If such is the case, the results might be most dramatic. The possibility of diffuse source control looks most promising when it is realized that the basins where sediment control is of economic advantage are the same ones producing the high phosphorus loads.

In summary, the biota of Lakes Erie and Ontario have undergone extreme changes since late 1800's, and these changes can be tied to the influence of man. Specifically, these changes were in the form of increased suspended solids and sedimentation, reducing light levels, covering rooted aquatic plants, and spawning grounds, and increased nutrient loads which enhanced phytoplankton growth and caused oxygen problems. The restriction of these pollutant inputs is most anxiously welcome, and the changes that will result will probably be most noticeable in the near future. The recovery of the biota will probably not be with the same species that were originally present as the loss of genetic pools has occurred. Some of the changes that have taken place within the lakes are irreversible. I believe we are now entering a phase of Great Lakes research where we can document the reversal of many of the adverse changes observed to date.

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DISCUSSION FOLLOWING THOMAS' ADDRESS

Dr. Rockwell: How do you tie the increase and changes in phosphorus and biota in the 1940's to the detergent phosphorus? Polyphosphates detergent was discovered in 1948, and introduced in 1950 or 1951.

Mr. Thomas: The increase in detergent use after the war period was also compounded by increased population growth. The initial phosphorus increase was a result of population growth, but the increase in the 1940's was due to the detergent formulation. Projections were based on a change in use of soap to detergent base. In the late 1940's, the use of detergent increased in comparison to soap.

Dr. Robertson: It is questionable whether the primary reason for bioperturbations was detergent or general population growth.

Mr. Thomas: The main population growth occurred in the late 1930's and 1940's.

Dr. Haffner: Research today uses the concepts of the "paradox of plankton" and spatial heterogeneity in biological communities among others. Is there sufficient knowledge to use community structures or look at changes in systems as opposed to investigating the loss of indicator

species? Can we use community analysis as opposed to individual or indicator species?

Mr. Thomas: Historically, the emphasis has been on indicator organisms. I have not seen a change in the direction in planning of surveys. Support within the regulating communities for doing phytoplankton, zooplankton, or benthos is poor. It is difficult to mount surveys where they are all present to do a system-wide analysis. This is partly the biologist's fault for not doing this in the past when resources were available as in the 1940's. In our agency, the amount of resources for aquatic biology is less than it was a few years ago. This is changing the philosophy on how we control the pollution. Biologists did not give the regulatory agencies enough information on how to manage the system based on water quality so this was changed to effluent requirements and eliminated the need for biologists. We are slowly coming around to the idea that systems do not respond to an effluent requirement. They respond to a load, so we are working our way back. If studies are done well, like the Bay of Quinte, and done small enough, there would be a chance to go to a whole lake system. In looking at the populations, it will be difficult because they are so cyclic.

Dr. Haffner: Great Lakes surveys are mostly on chemical analysis. Should we monitor chemistry so intensively or convert to biological community analysis?

Mr. Thomas: If we could sort out some of the climatic changes to the cyclic nature of the biological variations and relate them to chemical changes, we might have a chance. Not enough attention has been paid to long-term trends to sort out why benthos increases and decreases so radically from one year to the next. If you look at Lake Huron data for benthos, there were 3-4 good studies in the last 25 years. Population proportions are all over the place. The question is how would one design such a study. To look at a lake as a whole and get an indication of the population is very difficult.

Mr. Nicholls: You mentioned target loading of phosphorus in Lake Ontario. Are the desired levels of phosphorus concentration set in mind for the lake, or are they set at what is achievable at the sewage treatment plant in terms of treatment?

Mr. Thomas: The levels for Lake Ontario were based on the results from IFYGL. There was a dramatic shift in the basic production of the lake looking at zooplankton and phytoplankton. Using Vollenweider and Udolphos equations, a species shift occurred at 10 ppb. Numerical models were used to determine what load would relate to a phosphorus concentration of 10 ppb. A task force was set up to look at ways of achieving 7,000 metric tons. In Lake Erie, the target loading was based on trying to reduce the amount of anoxia (essentially reduce it 90%). The load of 11,000 metric tons was arrived at through numerical analysis of 3 to 4 different models. The treatment differed between the 1972 and 1978 agreement. In 1972, the agreement was based on 1 mg/l of all treatment plants over 1 million mg/d. The agreement in 1978 was based on water quality, the load associated with that, and not how to achieve it. That is what is in effect now, but the governments will negotiate it this spring.

Mr. Hamberger: You mentioned mirex as a contaminant in fishes. There was a ban on certain species of fish based on data from 1976. Was there a change in the concentration of mirex in fish?

Mr. Thomas: I am not aware of any changes since then. I was trying to relate an example of how an organic contaminant can reduce the usefulness of a fishery.

Mr. Hamberger: So the concentrations are still the same as when the bans were placed?

Mr. Thomas: There was more data put together on fisheries. The bans are state and provincial, and they can place and remove them at will.